6 ANALYSIS OF LIMITING FACTORS BY LIFE STAGE

Chapter 6 of the report summarizes and rates limiting factors presented in Chapter 5. Limiting factors are rated for degree of impact and synthesized in this chapter. This chapter includes an analysis of limiting factors by life stage and presents a series of limiting factors hypotheses and sub-hypotheses. These hypotheses are intended to serve as the scientific foundation for identifying recovery actions in the Lake Ozette sockeye recovery plan. The hypotheses cover all the limiting factors identified in this investigation; they are not restricted to key limiting factors. Each hypothesis presented in Sections 6.2.1 through 6.2.13 is supported by information presented in Chapters 1 through 5.

6.1 METHODS AND APPROACH

Each limiting factor hypothesis was evaluated based on the following definition of a limiting factor: physical, biological, or chemical conditions (e.g., inadequate spawning habitat, insufficient prey resources, or suspended sediment concentration) experienced by sockeye at the spawning aggregation scale, resulting in reductions in viable salmonid population (VSP) parameters (abundance, productivity, spatial structure, and diversity). Limiting factors that affect sockeye at this scale affect subpopulations and threaten the viability of the ESU. Key limiting factors are those with the greatest impacts on a population's ability to reach its desired status.

The Lake Ozette Steering Committee's technical workgroup evaluated and rated each of the limiting factors hypotheses based upon the degree of impact on the population or sub-population during each life stage. The degree of impact of each limiting factor was categorized as one of the following: unknown, negligible, low, moderate, or high. Figure 6.1 and Figure 6.2 depict the degree of impact assigned to each of the primary limiting factors by life stage. Table 6.1, Table 6.2, and Table 6.3 include all limiting factors ratings by life stage for each sub-population, as well as both sub-populations combined (during lake residency/adult holding).

Section 6.2 includes a narrative description of the degree of impact and certainty of impact based on the workgroup's limiting factors ratings. These ratings are qualitative and are based on the workgroup's knowledge of Lake Ozette sockeye. In addition, a narrative describing the rationale for determining a specific degree of impact and certainty of impact is included. It is important to note that many data gaps exist within the Ozette watershed and our understanding of limiting factors is based upon a limited number of studies and/or data limited to certain life history stages. Continued monitoring and additional studies are needed to fill data gaps in the future (see Chapter 7).

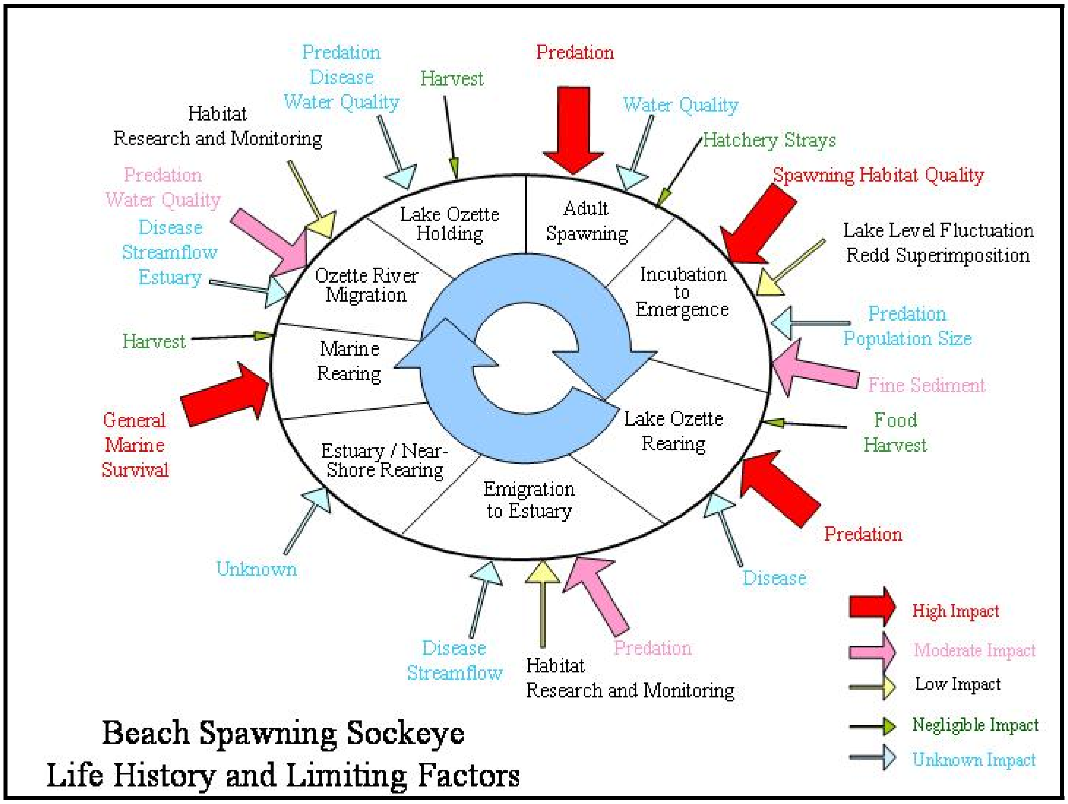

Figure 6.1. Beach spawning sockeye life history and rated limiting factors.

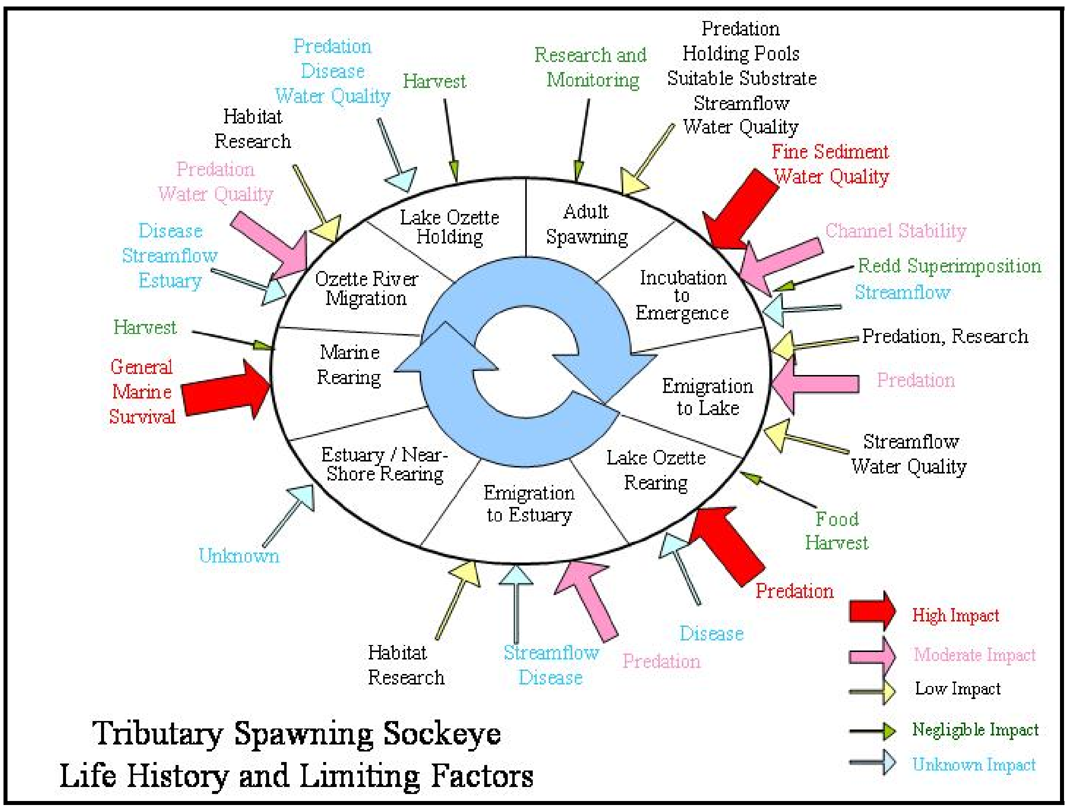

Figure 6.2. Tributary spawning sockeye life history and rated limiting factors.

Table 6.1. Limiting factors rating by life stage for both beach and tributary spawners during lake residency and adult holding.

SUB-POPULATION	LIMITING FACTOR	*LIFE HISTORY STAGE* ADULT SOCKEYE ENTERING THE SYSTEM	ADULT SOCKEYE HOLDING IN LAKE	JUVENILE PELAGIC REARING	JUVENILE EMIGRATION	MARINE ENVIRONMENT
BOTH BEACH AND TRIBUTARY SPAWNERS	Predation	**Moderate** Hypothesis 1 Section 6.2.1.1	**Unknown** Hypothesis 7 Section 6.2.2	**High** Hypothesis 41 Section 6.2.11.1	**Moderate** Hypothesis 45 Section 6.2.12.1	**NA**
	Ozette River stream habitat	**Low** Hypothesis 2 Section 6.2.1.2	**NA**	**NA**	**Low** Hypothesis 46 Section6.2.12.2	**NA**
	Water quality (suspended sediment and temperature)	**Moderate** Hypothesis 3 Section 6.2.1.3	**Unknown** Hypothesis 7 Section 6.2.2	**NA**	**Low** Hypothesis 47 Section 6.2.12.3	**NA**
	Ozette River streamflow	**Unknown** Hypothesis 4 Section 6.2.1.4	**NA**	**NA**	**Unknown** Hypothesis 48 Section 6.2.12.4	**NA**
	Tidal prism/estuary alterations	**Unknown** No Hypothesis Section 6.2.1.5	**NA**	**NA**	**Unknown** No Hypothesis Section 6.2.12.5	**NA**
	Directed harvest	**None** Hypothesis 5 Section 6.2.1.6	**None** Hypothesis 8 Section 6.2.2.2	**None** Hypothesis 42 Section 6.2.11.2	**None** Hypothesis 49 Section 6.2.12.6	**None** Hypothesis 51 Section 6.2.13.1
	Non-directed harvest	**NA**	**Negligible** Hypothesis 9 Section 6.2.2.2	**Negligible** Hypothesis 43 Section 6.2.11.2	**NA**	**Negligible** Hypothesis 52 Section 6.2.13.1
	Disease	**Unknown** No Hypothesis Section 6.2.1.7	**Unknown** Hypothesis 7 Section 6.2.2	**Unknown** No Hypothesis Section 6.2.11.3	**Unknown** No Hypothesis Section 6.2.12.7	**NA**
	Feeding/food availability	**NA**	**NA**	**Negligible** Hypothesis 44 Section 6.2.11.4	**NA**	**NA**
	Research and monitoring	**Low** Hypothesis 6 Section 6.2.1.8	**NA**	**NA**	**Low** Hypothesis 50 Section 6.2.12.8	**NA**
	Marine Survival	**NA**	**NA**	**NA**	**NA**	**High** Hypothesis 53 Section 6.2.13.2

Table 6.2. Limiting factors rating by life stage for beach spawners.

SUB-POPULATION	LIMITING FACTORS	*LIFE HISTORY STAGE*			
		ADULT SOCKEYE STAGING ON BEACHES	**ADULT SOCKEYE SPAWNING**	**EGG INCUBATION**	**FRY EMERGENCE AND MIGRATION TO PELAGIC ZONE**
BEACH SPAWNERS	Predation	**Low** Hypothesis 11 Section 6.2.3.1	**High** Hypothesis 11 Section 6.2.4.1	**Unknown** No Hypothesis Section 6.2.5.2	**Unknown** Hypothesis 18 Section 6.2.6.2
	Suitable spawning substrate (size, position, intra-gravel flow cond.)	**NA**	**NA**	**High** Hypothesis 13 Section 6.2.5.1	**NA**
	Fines in gravel (quality and quantity)	**NA**	**NA**		**Moderate** Hypothesis 17 Section 6.2.6.1
	Changes in shoreline vegetation (quality and quantity)	**NA**	**NA**		**NA**
	Seasonal lake level changes	**NA**	**NA**	**Low to Moderate** Hypothesis 14 Section 6.2.5.3	**Low to Moderate** Hypothesis 14 Section 6.2.6.3 and 6.2.5.3
	Water quality	**Unknown** No Hypothesis Section 6.2.3.2	**Unknown** No Hypothesis Section 6.2.4.2	**NA**	**NA**
	Small population size (habitat maintenance)	**NA**	**NA**	**Unknown** Hypothesis 16 Section 6.2.5.5	**NA**
	Competition (redd superimposition)	**NA**	**NA**	**Low to Moderate** Hypothesis 15 Section 6.2.5.4	**NA**
	Genetic impacts from tributary hatchery strays	**NA**	**Negligible** Hypothesis 12 Section 6.2.4.3	**NA**	**NA**

Table 6.3. Limiting factors rating by life stage for tributary spawners.

SUB-POPULATION	LIMITING FACTORS	*LIFE HISTORY STAGE*			
		ADULT SOCKEYE ENTERING TRIBUTARIES	**ADULT SOCKEYE SPAWNING**	**EGG INCUBATION**	**FRY EMERGENCE AND MIGRATION TO PELAGIC ZONE**
TRIBUTARY SPAWNERS	Predation	**Low** Hypothesis 19 Section 6.2.7.1	**Low** Hypothesis 24 Section 6.2.8.1	**Low** Hypothesis 36 Section 6.2.9.6	**Moderate** Hypothesis 38 Section 6.2.10.1
	Holding pools	**Low** Hypothesis 20 Section 6.2.7.2	**Low** Hypothesis 25 Section 6.2.8.2	**NA**	**NA**
	Suitable spawning substrate	**NA**	**Low** Hypothesis 26 Section 6.2.8.3	**NA**	**NA**
	Fines in gravel	**NA**	**NA**	**High** Hypothesis31 Section 6.2.9.1	**NA**
	Streamflow	**Low** Hypothesis 21 Section 6.2.7.3	**Low** Hypothesis 27 Section 6.2.8.4	**Unknown** Hypothesis 33 Section 6.2.9.3	**Low** Hypothesis 39 Section 6.2.10.2
	Channel stability and floodplain alterations (scour)	**NA**	**NA**	**Moderate** Hypothesis 32 Section 6.2.9.2	**NA**
	Interactions w/kokanee	**NA**	**Negligible to Low** Hypothesis 28 Section 6.2.8.5	**NA**	**NA**
	Water quality	**Low** Hypothesis 22 Section 6.2.7.4	**Low** Hypothesis 29 Section 6.2.8.6	**High** Hypothesis 34 Section 6.2.9.4	**Low** Hypothesis 40 Section 6.2.10.3
	Redd superimposition	**NA**	**NA**	**Neg. to Moderate** Hypothesis 35 Section 6.2.9.5	**NA**
	Research and monitoring	**Negligible** Hypothesis 23 Section 6.2.7.5	**Negligible** Hypothesis 30 Section 6.2.8.7	**Low** Hypothesis 37 Section 6.2.12.8	**NA**

6.2 LIMITING FACTORS HYPOTHESES BY LIFE STAGE

As described above, this section of the report presents a series of limiting factors hypotheses by life stage. Each hypothesis includes a narrative description of the degree of impact and certainty of impact in the workgroup's limiting factors rating. In addition, a narrative describing the rationale for determining a specific degree of impact and certainty of impact is included for each limiting factor hypothesis. Sub-hypotheses were developed for some complex limiting factors, which include linkage between each limiting factor and the processes and/or threats that may influence the limiting factor. Most sub-hypotheses include a link to the subsection of the report where detailed supporting evidence can be found. Not all sub-hypotheses include detailed narrative descriptions in other subsections of the report; some were included because members of the rating workgroup considered them important. The following limiting factors hypotheses are intended to serve as the scientific foundation for designing recovery actions for the Lake Ozette Sockeye Recovery Plan.

6.2.1 Adult Sockeye Salmon Entering System

The primary limiting factors affecting sockeye salmon entering the Ozette River and migrating to Lake Ozette include aquatic mammal predation (Section 6.2.1.1), Ozette River habitat conditions (Section 6.2.1.2), water quality (Section 6.2.1.3), and research and monitoring (Section 6.2.1.8). Additional limiting factors include reduced low flows (Section 6.2.1.4), changes in tidal prism and physical estuarine habitat conditions (Section 6.2.1.5), and disease (Section 6.2.1.7). The population impact of these additional limiting factors is unknown. No impact on sockeye salmon results from permitted in-river sport or tribal fisheries (Section 6.2.1.6).

6.2.1.1 Aquatic Mammal Predation

Hypothesis 1: Sockeye predation by aquatic mammals, primarily harbor seals and river otters in the Ozette River, estuary, and nearshore environment, reduces the number of effective spawners and therefore reduces the size of the sockeye population.

LEVEL OF IMPACT: Moderate
CERTAINTY OF IMPACT: Moderate

RATIONALE: Sockeye entering Lake Ozette have a high incidence of predator induced scarring and open wounds (~30-50%). A mark and recapture study conducted in 2000 (Gearin et al. 2002) indicates that 10% of the sockeye recaptured entering the lake were wounded by seals and otters in the Ozette River, while up to an additional 50% of the fish marked downstream were not successfully recaptured entering the lake, suggesting that a significant but unquantifiable level of aquatic mammal predation occurs in the river, estuary, and nearshore environment. The level of impact on the population is thought to increase as the run size decreases, so the actual level of impact was rated as moderate for periods of low abundance and low during periods of moderate to high abundance. Tributary sockeye can buffer the effects of predation on the beach spawning population by increasing the number of sockeye entering freshwater and potentially "swamping" predators (see Sections 5.2.2 and 5.3.4).

Hypothesis 1A: Increases in the abundance of aquatic mammal predators within and adjacent to the Ozette watershed have increased the number of sockeye salmon killed by aquatic mammal predators (Sections 5.2.2.2.1, 5.2.2.2.2, 5.3.4.2.2, and 5.3.4.2.6).

Hypothesis 1B: Abandonment of the Ozette Village and fishing stations on the Ozette River have led to an increased number of aquatic mammals preying upon sockeye salmon within the estuary and river (Section 5.2.2.2.2).

Hypothesis 1C: The depressed nature of the Lake Ozette sockeye population influences the effect of aquatic mammal predation on the sockeye population. Low abundance of sockeye increases the rate of predation (Section 5.2.2.2.3).

Hypothesis 1D: Changes in the streamflow regime of the Ozette River affect migration conditions encountered by sockeye salmon, reduce predator avoidance capabilities and enhance predation efficiencies (Section 5.3.4.2.4).

Hypothesis 1E: Large woody debris removal has reduced the quantity and quality of pool habitat in the Ozette River. Resultant reduced pool depth, volume, and cover decreased predator avoidance capabilities and refuge areas for sockeye, increasing predator efficiency (Section 5.3.4.2.1).

Hypothesis 1F: Operation of the adult sockeye counting weir and smolt trap act as a bottleneck for migrating adult sockeye, increasing their susceptibility to predation (Section 5.3.4.2.7).

Hypothesis 1G: Large woody debris removal has enhanced the migration conditions for aquatic mammals in the Ozette River, allowing for unimpeded passage upstream; this influences harbor seals' ability to prey upon sockeye in the river (as well as providing unobstructed access to the lake during most flow conditions -; Section 5.3.4.2.1).

6.2.1.2 Ozette River Habitat Conditions

Hypothesis 2: Large woody debris removal has reduced the quantity and quality of pool habitat in the Ozette River. Resultant reduced pool depth, volume, and cover decreased predator avoidance capabilities and refuge areas for sockeye, increasing predator efficiency and reducing refuge habitat.

LEVEL OF IMPACT: Low

CERTAINTY OF IMPACT: Moderate

RATIONALE: The loss of large (>50 cm diameter) LWD in the Ozette River through removal operations has undoubtedly resulted in reduced habitat complexity throughout much if not all of the Ozette River. Riparian forest removal adjacent to the upper 0.4 miles of the Ozette River have reduced LWD inputs, delaying the recovery and habitat potential of the upper river. Adult sockeye spend a limited amount of time in the Ozette River, reducing their exposure to degraded habitat conditions. Habitat simplification mainly affects adult sockeye by reducing refuge habitat, making sockeye more susceptible to predation (Section 5.3.4.2.1).

6.2.1.3 Water Quality

Hypothesis 3: High stream temperatures and low frequency, high intensity turbidity events reduce the fitness of sockeye salmon entering Lake Ozette, and result in increased egg retention and pre-spawning mortality; in some cases, high stream temperatures exceeding 20°C result in direct en route mortality.

LEVEL OF IMPACT: Moderate
CERTAINTY OF IMPACT: Moderate

RATIONALE: High stream temperatures and low frequency, high intensity turbidity events occur during the sockeye migration period. Temperatures approaching 24°C have been recorded during the adult migration period. Sockeye covered in silt and bleeding from the gills have been observed following high turbidity and suspended sediment concentrations (hereafter, "SSC") events. Cumulatively, approximately 12% of the population on average would be exposed to high SSC events based upon the frequency and duration of these events during the migration period. These events would result in moderate physiological stress (Newcombe and Jansen 1996) based on the expected sockeye exposure times, which are a function of average measured migration times (Gearin et al. 2002). The level of impact of this limiting factor hypothesis was rated as moderate primarily based upon temperature impacts. Collectively, poor water quality conditions, especially during the later part of the run, are cause for concern (see Sections 4.3.5, 5.3.3, 5.3.3.1, 5.3.3.1.1, 5.3.3.1.2, and 5.3.3.2).

Hypothesis 3A: High stream temperatures in the Ozette River are a natural condition (see Sections 5.3.3.1, 5.3.3.1.1, and 5.3.3.1.2). However, increased summer air temperatures resulting from climate change have increased average water temperatures during the sockeye migration period by 1 to 2°C (based on average air temperature increases observed during the last 90 years for the months of June, July, and August in Forks WA). Continued and predicted climate change will likely continue to increase the temperature of the Ozette River, negatively affecting adult migrants.

Hypothesis 3B: The high road density (6.1 mi/mi^2), extensive clear cutting (98% of watershed clear-cut at least once), and channel incision (e.g., from LWD removal in the Ozette River) in the Coal Creek watershed have resulted in degraded water quality conditions (turbidity and SSC) in Coal Creek (Sections 4.4.4.4, 4.4.4.5, and 4.4.4.5.1) and the Ozette River to the detriment of migrating adults' health and survival (Sections 4.3.4, 4.3.5, 5.3.3, and 5.3.3.2).

Hypothesis 3C: Removal of LWD has resulted in decreased depth, complexity and availability of pools that serve as refuge areas from temperature (and low flows), resulting in higher stress potential during migration (Sections 4.3.3, 5.3.3.1, 5.3.3.1.1, and 5.3.3.1.2.

Hypothesis 3D: Warmer water temperatures, earlier in the season, have shifted marine area migration and freshwater entry timing earlier during the last 30 years.

6.2.1.4 Streamflow

Hypothesis 4: Sedimentation in the Ozette River from Coal Creek has reduced the quantity of water available as streamflow from the lake at a given stage. Changes in this stage discharge relationship, changes in hyporheic and surface flow conditions, increased lake evapotranspiration, and reductions in tributary baseflow inputs have reduced summer low flows. Reduced streamflows affect water quality, predation rates and efficiency, and migration, reducing the fitness of migrating adult sockeye.

LEVEL OF IMPACT: Unknown
CERTAINTY OF IMPACT: NA

RATIONALE: Available discharge data for the Ozette River at the lake outlet indicate a clear trend of decreasing baseflow (summer discharge) over time from the 1970s to 2000s (See Figure 4.33, Figure 4.42, Figure 4.44). The decrease is likely caused by multiple factors acting cumulatively over time.

Available data do not indicate that climatic controls on precipitation or lake level have changed dramatically over time to influence Ozette River discharge. Rather, internal mechanisms are at play (see Section 5.3.2.2.1.1). A significant change in the stage-discharge relationship occurred in the Ozette River between 1979 and 2002 (Section 4.3.6; Figure 4.37), indicating that discharges in Ozette River are lower for a given stage in 2002 compared to 1979 (Section 5.3.2.2.1.2). The percentage of hyporheic flow to total flow may have changed due to sedimentation near the confluence of the Ozette River and Coal Creek (Section 5.3.2.2.1.3). Shoreline vegetation colonization of the perimeter of Lake Ozette has increased evapotranspiration, potentially influencing lake levels and thus river discharge (Section 5.3.2.2.1.4). Summer base flows to Lake Ozette may have declined due the effects of land use on fog drip, summer transpiration efficiency of dominant vegetation, soil water retention, and floodplain water storage (Section 5.3.2.2.1.5). These hypothesized reductions in summer water inputs to Lake Ozette could translate to reduced Ozette River discharge.

Reduced streamflow has the potential to affect water quality, predation rates and efficiency, and migration, reducing the fitness of migrating adult sockeye. For example in RY 2003 just under 38% of the sockeye entered when lake levels were less than 100 cfs. Approximately 10% of the RY 2003 sockeye entered the lake when flows were less than 35 cfs and the lowest flow in which sockeye were observed migrating was 11 cfs. The overall decrease in baseflow (summer discharge) during the sockeye migration period remains unknown and the relative contribution of the aforementioned factors is poorly understood, as are the biological effects.

6.2.1.5 Tidal Prism and Physical Estuarine Habitat Conditions

Changes in the tidal prism and estuarine habitat conditions appear to have occurred during the last 50 years (see Section 4.1). The cause of these apparent changes is poorly understood, as are the potential effects on Lake Ozette sockeye.

6.2.1.6 Fisheries Impacts

Hypothesis 5: There are no open fisheries within the Ozette River during the adult sockeye migration period and therefore there are no impacts on sockeye salmon from in-river fisheries.

LEVEL OF IMPACT: None
CERTAINTY OF IMPACT: High

RATIONALE: The river is closed to all sport fishing until August 1st. When the river is open, selective fishery rules apply and all sockeye must immediately be released. There are no non-directed fishery impacts during the adult migration due to permitted fisheries. No tribal salmon fisheries are conducted within the watershed (see Section 5.2.3). Some poaching may occur but poaching has not been documented by the NPS.

6.2.1.7 Disease

No systematic monitoring of sockeye health in the river occurs. Observations of infections and fungus growth are occasionally included in weir observation notes but no systematic inventory data are collected. Trapping work conducted in during RY 2000 visually examined 899 sockeye for external tags and physical condition. Less than 1% of the sockeye transiting the weir had visible fungal growth. However, at least some individual sockeye have been observed with severe external infections and likely die prior to reaching the spawning grounds (see Section 5.4.6).

6.2.1.8 Research and Monitoring

Hypothesis 6: Operation of the adult sockeye counting weir and smolt trap result in limited, if any, direct impacts on sockeye resulting from encounters with counting equipment. However, the weir acts as a bottleneck for migrating adult sockeye, increasing their susceptibility to predation, and delays upstream migration, increasing exposure time to poor water quality conditions.

LEVEL OF IMPACT: Low
CERTAINTY OF IMPACT: High

RATIONALE: No direct mortalities at the weir resulting from encounters with weir and smolt trapping equipment have been documented. However, adult sockeye migrating into the lake are especially susceptible to predators as they transit the weir. The weir acts as a bottleneck to migrating sockeye; harbor seals and river otters appear to use the weir as an aid in hunting. Seals and otters have frequently been observed working the face of the weir, swimming back and forth across the river in search for sockeye. It appears that the degree to which the weir and trapping operations increase adult sockeye salmon susceptibility to predation increases as lake level declines (see Section 5.3.4.2.7). The counting weir may also delay migrants from entering the lake and increase their exposure time to elevated stream temperatures and/or high SSC. Weir operations since 1998 have been conducted with the weir left open 24 hrs/day to allow free passage into the lake in order to minimize impacts of high water quality and predation caused by the weir (5.3.3.1.2).

6.2.2 Adult Sockeye Holding in Lake Ozette

The primary limiting factors affecting sockeye salmon holding in Lake Ozette include predation, disease, and water quality (Section 6.2.2.1). Negligible impacts were attributed to sport fisheries occurring within the lake (Section 6.2.2.2).

6.2.2.1 Predation, Disease, and Water Quality

Hypothesis 7: The number of sockeye surviving to spawn is reduced by predators, disease, and other factors during the extended holding period in Lake Ozette prior to spawning.

LEVEL OF IMPACT: Unknown
CERTAINTY OF IMPACT: NA

RATIONALE: The disposition of adult sockeye entering the lake and holding for several months prior to spawning is unknown. Assessment of population status and mortality rates during the holding period is complicated by the relatively large size of the lake, the small size of the population, sockeye holding behavior, and limnological conditions that limit direct observations of sockeye mortalities and the number of sockeye surviving to spawn in the lake. Limiting factors affecting sockeye holding in Lake Ozette include: (1) predation by aquatic mammals (see Sections 5.4.5, 5.4.5.1.1, and 5.4.5.1.2): (2) disease (see Section 5.4.6): and (3) delayed pre-spawning mortality related to decreased fitness (e.g. from elevated temperature; see Sections 4.2.3, 4.3.5, 4.3.6, 5.3.2.2, 5.3.3.1, 5.3.3.1.1, 5.3.3.1.2, and 5.3.3.2) or a combination of these factors. The degree to which any of these factors limit sockeye survival is unknown and remains a data gap.

6.2.2.2 Fisheries Impacts

Hypothesis 8: Very low numbers (if any) of sockeye are caught in ONP's Lake Ozette catch and release fishery.

LEVEL OF IMPACT: Negligible
CERTAINTY OF IMPACT: Moderate

RATIONALE: The lake is open to catch and release salmon fishing and therefore there are potential impacts on sockeye attributable to directed salmon fisheries occurring in the lake. However, it is unlikely that individuals actually target sockeye in the lake. There are no data regarding fishing pressure (e.g. angler days) or targeted sockeye encounters within the lake. The above conclusions are based on experience and knowledge of the Lake Ozette sport fisheries by members of the limiting factors rating workgroup.

Hypothesis 9: Incidental hooking and catching of sockeye salmon occurs at an extremely low level within the lake during sport fisheries targeting trout, bass, or other non-salmon species. Incidental hooking or catching of sockeye salmon has a negligible effect on the sockeye population.

LEVEL OF IMPACT: Negligible
CERTAINTY OF IMPACT: Moderate

RATIONALE: Lake Ozette is large and currently only a few thousand adult sockeye are present within the lake at any given time, reducing the likelihood of incidental hooking in sport fisheries targeting other species. Sockeye salmon are typically poor biters in freshwater, a behavior that further reduces the probability of incidental hooking. Additionally, Lake Ozette has low fishing pressure, which also reduces the potential impact of incidental hooking and/or catching within the lake. There are no data regarding fishing pressure (e.g. angler days) or non-targeted sockeye encounters within the lake; these conclusions are based on the experience and knowledge of members of the limiting factors rating workgroup about the Lake Ozette sport fisheries.

6.2.3 Adult Sockeye Staging at Spawning Beaches

The primary limiting factors affecting sockeye salmon staging along the spawning beaches are predation (Section 6.2.3.1) and water quality (Section 6.2.3.2).

6.2.3.1 Predation

Hypothesis 10: Predation of adult sockeye salmon primarily by harbor seals and river otters during the pre-spawning staging period reduces the number of effective spawners and therefore reduces the size of the sockeye population.

LEVEL OF IMPACT: Low
CERTAINTY OF IMPACT: Low

RATIONALE: Indirect observational data suggests that sockeye salmon are much less vulnerable to predation during the pre-spawning staging period because the fish hold offshore, in deeper water, and at lower densities, making them less susceptible to predation. Most pre-spawning mortality from predation is thought to occur on the spawning grounds rather than in the off-shore staging environment. However, no direct estimates of predation-related mortality have been made during the sockeye staging period. High impacts on sockeye are attributed to predation on the spawning grounds (see Sections 5.4.5, 5.4.5.1.1, 5.4.5.1.2, and 6.2.4.1).

6.2.3.2 Water Quality

The effects of water quality on sockeye salmon during the staging period are unknown and remain a data gap. However, limited water quality data collected in the offshore environment suggest that conditions are favorable for sockeye and that water quality is not likely a significant limiting factor during this life history stage. Sockeye are exposed to less optimal water quality conditions closer to the shoreline and near tributary outfalls (see Sections 5.4.3 and 6.2.4.2). For a complete review of water quality conditions see Sections 4.2.3, 4.4.1.5, 4.4.2.5, 4.4.3.5, 4.4.4.5, 4.4.5.5, 5.3.3, 5.3.3.1, 5.3.3.1.1, 5.3.3.1.2, and 5.3.3.2

6.2.4 Adult Sockeye Spawning on Lake Beaches

Predation (Section 6.2.4.1) is the primary limiting factor affecting sockeye salmon spawning on the beaches. Other limiting factors identified are water quality (Section 6.2.4.2) and genetic impacts from tributary hatchery strays (6.2.4.3).

6.2.4.1 Predation

Hypothesis 11: Predation of adult sockeye salmon primarily by harbor seals and river otters reduces the number of effective spawners and therefore reduces the size of the sockeye population.

LEVEL OF IMPACT: High
CERTAINTY OF IMPACT: Moderate

RATIONALE: Data collected during the spawning season in 2000 suggest that 40% or more of the sockeye at Allen's Beach were killed by harbor seals and river otters prior to completion of spawning. Data from Olsen's Beach during the same year indicates that approximately 10% of the spawners were killed by seals and otters. Both predatory mammal species have been observed foraging at known beach spawning areas during the sockeye spawning period. Continued monitoring is needed to fully document the degree of predation occurring, but the limited data collected to date indicate the potential for substantial predation on the spawning grounds (see Sections 5.4.5, 5.4.5.1.1, and 5.4.5.1.2).

Hypothesis 11A: Increases in the abundance of aquatic mammal predators within the Ozette watershed have led to an increase in the number of sockeye salmon killed by aquatic mammal predators (Sections 5.2.2.2.1, 5.2.2.2.2, 5.3.4.2.2, and 5.3.4.2.6).

Hypothesis 11B: Abandonment of the Ozette Village and fishing stations on the lake has led to an increase in the number of aquatic mammals preying upon sockeye salmon in the lake and on the spawning beaches (Section 5.2.2.2.2).

Hypothesis 11C: Protections afforded by the Federal Marine Mammal Protection Act and by anti-hunting/trapping rules implemented by ONP have contributed to the increasing number of aquatic mammal predators on spawning beaches, resulting in increased sockeye pre-spawning mortality due to predation (Sections 5.2.2.2.1 and 5.3.4.2.6).

Hypothesis 11D: The depressed nature of the Lake Ozette sockeye population enhances the effect of aquatic mammal predation on the sockeye population; low abundance of sockeye increases the realized rate of predation (Section 5.2.2.2.3).

Hypothesis 11E: Predation on sockeye congregating on the spawning beaches is a newly developed strategy for harbor seals. No seals were observed in the lake until the mid- to late1980s, and, with this new behavior, it can be assumed that predation impacts on beach spawning sockeye have increased relative to historical levels (Section 5.4.5.2.2).

6.2.4.2 Water Quality

High turbidity and SSC levels in tributaries to the lake can result in high turbidity levels along the lake shoreline. The frequency of high turbidity events and the direct effect on spawning sockeye are unknown but may include moderate physiological stress, habitat avoidance, and spawning habitat degradation. Turbidity and SSC data are lacking on the extant spawning beaches and are considered an important data gap. In general, existing beach spawning habitats, especially Allen's Beach, are less susceptible to stream-derived turbidity and SSC (due to proximity to major sediment sources from eastern tributaries). However, at historical spawning sites, such as Umbrella Beach, turbidity impacts are expected to be similar to those in Umbrella Creek (see Section 6.2.8.6).

6.2.4.3 Tributary Hatchery Program Impacts

Hypothesis 12: Straying of tributary hatchery program sockeye adults to beach spawning areas adversely affects the genetic diversity and fitness of the beach spawning population.

LEVEL OF IMPACT: Negligible
CERTAINTY OF IMPACT: High

RATIONALE: Hatchery practices implemented through the HGMP include measures to minimize potential disease and genetic impacts on beach spawning aggregations (see Sections 3.2.3 and 5.4.7). Imprinting juvenile sockeye using on-station rearing in release watersheds reduces the risk of hatchery-origin sockeye straying onto beaches. Mark and recapture data collected at Olsen's and Allen's beaches indicates that few if any Umbrella Creek hatchery releases return to spawn on Lake Ozette beaches. Approximately 25% of the BY 1995 Umbrella Creek fed fry released were adipose fin clipped and in 1999, 121 adult sockeye salmon were sampled on Olsen's Beach and none were adipose fin clipped. This suggests that straying from tributary releases onto spawning beaches was nonexistent or at least very low (MFM 2000). Spawning adults returning from hatchery releases after 1999 were mass marked using thermal otolith marks (100% marking), as well as fin clips (45% of all fry and fingerlings since BY 1999 have been fin clipped) allowing for monitoring of hatchery-origin fish throughout the watershed. The results from otolith sampling are not yet available. Also, note that sockeye straying onto Olsen's Beach are likely to have a limited genetic impact if successful spawning occurs, since Olsen's and Umbrella Creek sockeye share common genetics (Hawkins 2004).

6.2.5 Sockeye Egg Incubation on Beaches

The primary limiting factors affecting sockeye salmon egg incubation on the beaches include reduced spawning habitat quality and quantity (Section 6.2.5.1), predation (Section 6.2.5.2), and seasonal lake level changes (Section 6.2.5.3). The small population size on the spawning beaches during the last 30-40 years has had an unknown degree of impact on the quality and quantity of spawning habitat (see Section 6.2.5.5).

Competition (Section 6.2.5.4) for reduced spawning area has also been identified as a limiting factor affecting the recovery of Ozette sockeye.

6.2.5.1 Reduced Spawning Habitat Quality and Quantity

Hypothesis 13: Reduced quality and quantity of beach spawning habitat in Lake Ozette has decreased egg to emergence survival, resulting in reduced fry production from the beach spawning aggregations.

LEVEL OF IMPACT: High
CERTAINTY OF IMPACT: High

RATIONALE: The quality and quantity of beach spawning habitat varies by spawning beach and site within each of the extant spawning beaches (see Section 4.2.1). The results of egg incubation studies on Olsen's Beach strongly suggest that egg survival is extremely poor (<<10%) within most of the primary spawning area. Not all egg mortality in tests could be explained by fine sediment concentrations alone. Several environmental variables are likely at work collectively reducing egg survival. Sockeye salmon egg-to-fry survival on Lake Ozette beaches is limited by lack of adequate oxygen exchange from incubation water to the eggs, caused independently by two primary factors and their synergistic interactions: 1) reduced intergravel flows and 2) high levels of fine sediment (i.e. < 0.85mm). Fine sediment levels and intergravel flows are partially controlled by lake level, wave energy, tributary sediment inputs, vegetation, seasonal groundwater levels, and other mechanisms. The synergistic effects of multiple variables (inputs/processes/actions) that interact to limit egg to emergence survival make it extremely difficult to link each specific process or input to a specific level of impact. Cumulatively, incubation conditions (lake level, fine sediment, vegetation, intra-gravel flow, etc…) on the spawning beaches are poor and the impact was therefore rated as high (see Section 5.4.2.1).

Fine sediment levels exceed 25% (dry method; wet sieve equivalent ~37%) on the remaining spawning beaches. Fine sediment levels exceed 50% at Umbrella Beach (from Herrera 2006). Increased sediment production in tributaries and delivery to spawning beaches have decreased the quantity of spawning habitat available (see Sections 5.4.2.2 and 5.4.2.2.1). The total quantity of spawning habitat eliminated because of increased fine sediment deposition altering substrate size and character is unknown, but at least one entire spawning beach has been lost (Umbrella Beach). Quantification of lost spawning habitat due to lake level alterations from wood removal in the Ozette River is presented in detail in Section 5.4.2.2.2. Vegetation colonization along the shoreline of the lake between 1953 and 2003 resulted in a 56% net decrease in the quantity of unvegetated shoreline (Section 5.4.2.2.3).

The Olsen's Beach spawning population has been reduced to very few individuals in the recent past (see Figure 3.25) and has rebounded back to several hundred spawners in following years, suggesting that a limited amount of highly productive spawning habitat may still exist at Olsen’s Beach.

Hypothesis 13A: Large woody debris removal from the Ozette River has reduced average lake levels during the spawning and incubation period, resulting in decreased spawning habitat availability, especially along the upper margins of shallow beach areas (Section 5.4.2.2.2).

Hypothesis 13B: Wood removal from Ozette River, coupled with alteration of watershed hydrology by land use, has changed the variability of lake levels, which has reduced the time that spawning habitat is available or that redds are covered in water (Sections 4.2.5, 5.4.1, 5.4.1.1, and 5.5.1.2.2).

Hypothesis 13C: Alterations in lake level variability from lake-outlet wood removal and tributary-inflow hydrologic change, coupled with tributary wood removal and channel incision, have altered hyporheic and groundwater hydraulics and hydrology. Altered hydrology shifted emergent (upwelling) hyporheic or groundwater rates and locations (lateral and vertical) along the shoreline of the lake and tributary deltas, thereby reducing egg-to-fry survival on historically used spawning beaches. (Note: this sub-hypothesis has not been thoroughly investigated and there are no supporting data.)

Hypothesis 13D: Extensive road construction has altered groundwater hydrology, shifting emergent (upwelling) groundwater rates and locations (lateral and vertical) along the shoreline of the lake, thereby reducing egg-to-fry survival on historically used spawning beaches (Note: this hypothesis has not been thoroughly investigated and there are no supporting data.)

Hypothesis 13E: Large woody debris removal from Ozette River has reduced average lake levels during the growing season and enhanced the ability of vegetation to colonize beach spawning habitat and trap fine sediment (Sections 5.4.2.1.1.3 and 5.4.2.2.3; see also Herrera 2005).

Hypothesis 13F: Vegetation encroachment along the shoreline of Lake Ozette during the last 30-100 years has significantly decreased the quality and quantity of beach spawning habitat available (Sections 4.2.1, and 5.4.2.1.1.3).

Hypothesis 13G: Large woody debris removal from Ozette River has reduced average lake levels, resulting in channel incision in tributaries and a subsequent release of stored sediment into the lake and beach spawning habitats, contributing to the elimination of at least one of the historical spawning sub-populations (Umbrella Beach) (Section 5.4.2.1.1.1; see also Herrera 2005, 2006).

Hypothesis 13H: Increased sediment production in tributaries from land use activities (e.g. road building, clearcut logging, etc) and delivery to lake beaches has decreased the quantity and quality of beach spawning habitat that is available for successful egg incubation, contributing to the elimination of at least one of the historical spawning sub-populations (Umbrella Beach; Section 5.4.2.1.1.1).

Hypothesis 13I: Small beach spawning population sizes during the last 30-40 years have been incapable of maintaining suitable spawning habitat and mitigating the increased levels of fine sediment and vegetation along beach spawning habitats (Section 5.4.2.1.1.2).

Hypothesis 13J: Reduced spawning habitat quality and quantity have increased competition for suitable habitat at low to moderate spawning escapement levels, resulting in increased redd superimposition and decreased egg-to-fry survival (see Section 6.2.5.4).

6.2.5.2 Egg Predation

Egg predation occurs at unknown levels on the spawning beaches. Known predators of sockeye eggs at Lake Ozette include sculpins (see Sections 2.2.2 and 5.4.5.1.5) and aquatic insects (see Section 5.4.5). Currently there is no evidence that suggests that egg predation has increased relative to historical baseline levels. However, at low spawning escapement levels egg predation could play an important role in limiting population growth as a result of the potential depensatory effects of predation.

6.2.5.3 Seasonal Lake Level Changes

Hypothesis 14: Seasonal lake level changes result in redd dewatering limiting survival to emergence.

LEVEL OF IMPACT: Low to Moderate
CERTAINTY OF IMPACT: High

RATIONALE: The level of impact varies depending upon redd elevations relative to water surface elevation at emergence. Detailed redd mapping on Olsen's Beach during the winter of 2000/01 indicated that approximately 3% of the total redd surface area (7 total redds) was completely dewatered at the time of emergence. Spawning surveys conducted between 1999 and 2004 do not indicate that high levels of redd dewatering are occurring in Lake Ozette (see Section 5.4.1.1). However, high lake levels early in the spawning season followed by drought conditions would likely result in moderate levels of redd dewatering when winter lake levels reach levels below 33 ft (MSL- NGVD 1929).

6.2.5.4 Competition (Redd superimposition)

Hypothesis 15: Reduced spawning habitat quality and quantity have increased the competition for suitable habitat at low to moderate spawning escapement levels, resulting in increased redd superimposition and decreased egg-to-fry survival.

LEVEL OF IMPACT: Low to Moderate
CERTAINTY OF IMPACT: Moderate

RATIONALE: The impact was rated as moderate for the Olsen's Beach core spawning area and low for all other sites. Redd superimposition on the spawning beaches is thought to significantly reduce the survival of earlier deposited eggs on the spawning beaches. The degree to which this is occurring is difficult to measure but sockeye spawning on Olsen's Beach seem to be especially prone to multiple spawning events in the same location during the same season. As described in Section 3.1.4, during RY 2000, sockeye were observed spawning in the same location over an 89-day period and more than 90% of the redd surface area measured had been spawned-in multiple times during the spawning season. These observations provide additional evidence that suitable/preferred spawning area is limited. Since Ozette sockeye appear to prefer areas with springs and seeps for spawning, it is thought that alterations in the location, degree, and depth of upwelling could negatively affect beach spawning; although no such alterations have been documented (see Section 5.4.2.3).

6.2.5.5 Small Population Size

Hypothesis 16: Small beach spawning population sizes during the last 30-40 years have been incapable of maintaining suitable spawning habitat and mitigating fine sediment inputs and vegetation colonization along some of the beach spawning habitats.

LEVEL OF IMPACT: Unknown
CERTAINTY OF IMPACT: NA

RATIONALE: The small beach spawning aggregations that have persisted during the last 30 years may have been reduced to levels incapable of sufficiently cleaning spawning gravels and maintaining vegetation-free spawning gravels. During the act of spawning, salmonids winnow fine sediment from spawning substrate (Kondolf et al. 1993). Lack of sufficient numbers of spawners could result in degraded habitat conditions, as well as increased levels of fine sediment within spawning gravels. The reduction of mass spawning fish populations such as sockeye, as a result of other limiting factors (e.g. overfishing) has been hypothesized to create a negative feedback loop due to reduced gravel bed maintenance of fine sediment levels in lake or streams, or scour depths in streams (Montgomery et al. 1996; see Section 5.4.2.1.1.2).

6.2.6 Lake Beach Fry Emergence and Dispersal

The primary limiting factors affecting sockeye salmon egg incubation on the beaches include fine sediment (Section 6.2.6.1), predation (Section 6.2.6.2), and seasonal lake levels changes (Section6.2.6.3).

6.2.6.1 Fine Sediment

Hypothesis 17: Fine sediment deposition in sockeye redds reduces the ability of surviving fry to emerge from gravel.

LEVEL OF IMPACT: Moderate
CERTAINTY OF IMPACT: Moderate

RATIONALE: Fine sediment levels exceed 25% (dry method; wet sieve equivalent ~37%) on the remaining spawning beaches . Fine sediment levels exceed 50% at Umbrella Beach (from Herrera 2005). Egg incubation studies conducted in 2000 and 2001 found that fine sediment deposition on redds occurred during egg incubation. Fine sediment deposition during incubation can form an impenetrable layer of fine sediment, impeding emergence. Poor survival from eyed egg to pre-emergence indicates that the majority of mortality occurs prior to emergence. Therefore the level of impact was defined as moderate (see Sections 5.4.2.1, 5.4.2.1.1, and 5.4.2.1.1.1).

6.2.6.2 Predation

Hypothesis 18: Predation of sockeye fry during emergence reduces the number of fry rearing in the pelagic zone of the lake.

LEVEL OF IMPACT: Unknown
CERTAINTY OF IMPACT: NA

RATIONALE: The level of impact of predation at emergence in unknown. A number of species of aquatic predators exist throughout the littoral zone. Directly upon emergence, sockeye fry are vulnerable to non-native piscivorous species such as largemouth bass and yellow perch. Small numbers of beach spawners and poor egg-to-fry survival can make juvenile sockeye vulnerable to the depensatory effects of predation at reduced abundance. Predator interactions at this early life history stage remain a data gap, but it is possible that significant levels of predation occur in the vicinity of the spawning beaches.

6.2.6.3 Seasonal Lake Level Changes

Seasonal lake level effects during emergence are the same as those examined for egg incubation above, see Section 6.2.5.3.

6.2.7 Adult Sockeye Entering, Migrating, and Holding in Tributaries

Several factors were evaluated for their impacts on adult sockeye entering, migrating, and holding in Lake Ozette tributaries, including predation (Section 6.2.7.1), holding pool quantity and quality (Section 6.2.7.2), streamflow (Section 6.2.7.3), water quality (Section 6.2.7.4), and research and monitoring (Section 6.2.7.5).

6.2.7.1 Predation

Hypothesis 19: Adult sockeye predation in tributaries occurs at low levels and is not likely a significant limiting factor.

LEVEL OF IMPACT: Low
CERTAINTY OF IMPACT: Moderate/High

RATIONALE: Hughes et al. (2002) concluded that there is very little evidence of pre-spawning predation mortality in Umbrella Creek based on tagging, tracking, genetic sampling, and spawning ground surveys. In 2000, seven adult sockeye tagged with CART tags were tracked in Umbrella Creek and all were observed to have successfully spawned (see Sections 5.5.5, 5.5.5.1, 5.5.5.1.1, 5.5.5.1.2, and 5.5.5.2).

6.2.7.2 Holding Pool Quantity and Quality

Hypothesis 20: Current holding pool frequency and volume has a limited effect on adult sockeye salmon survival during the migration and holding period.

LEVEL OF IMPACT: Low
CERTAINTY OF IMPACT: High

RATIONALE: Holding pool frequency downstream of the primary spawning areas in Umbrella Creek and Big River is good or fair in most channel segments (Figure 4.49 and Figure 4.59); however, some segments in Big River have reduced pool volume due to lack of wood and pool filling by sediment aggradation. Other pool attributes (e.g. percent woody cover) have reduced quality in many of the channel segments within Umbrella Creek and Big River (see Sections 4.4.1.3, 4.4.2.3, and 5.5.4.1). Female sockeye, while preparing to spawn, will frequently be attacked by adjacent territorial females; therefore, females preparing to spawn will often hold in pools before moving onto the spawning grounds (Quinn 2005). As tributary sockeye population sizes increase, the quantity and quality of pool habitat will become more important.

6.2.7.3 Streamflow

Hypothesis 21: Prolonged periods of low streamflow during the fall delays adult migration into tributaries, thus increasing sockeye exposure to predation events near the mouths of streams and reducing their fitness, increasing egg retention and pre-spawning mortalities.

LEVEL OF IMPACT: Low
CERTAINTY OF IMPACT: Low

RATIONALE: Delayed migration of sockeye into tributaries during October and November has been observed during extreme low base flow conditions and a delay in the onset of the wet season (i.e., the first few rains). The population impact of delayed migration due to streamflow is thought to be low. Unlike sockeye spawning in shallow water at beaches, sockeye congregating near tributary mouths are more flexible in their holding depths and locations, enabling fish to minimize predator interactions. Climatic variability in precipitation timing is a natural phenomenon that sockeye salmon have adjusted to. Land use changes in hydrological processes would not be expected to change the timing of migration flows, which are dependent on climatic precipitation inputs. However, land use could affect low base flow magnitudes to a currently unknown degree, which, under natural conditions with higher sustained base flows, may have allowed sockeye to migrate into tributaries earlier in the spawning season. Climate change in the future could alter the timing of the onset of the wet season (i.e., the first few rains).

6.2.7.4 Water Quality

Hypothesis 22: Elevated turbidity and SSC levels increase stress and reduce sockeye fitness, resulting in increased egg retention rates and pre-spawning mortalities.

LEVEL OF IMPACT: Low
CERTAINTY OF IMPACT: Moderate

RATIONALE: High turbidity levels, which are an indicator of SSC, have been recorded in Ozette spawning tributaries, especially Umbrella Creek and Big River (peak values >500 NTU). Peak streamflow and turbidity events are common during the sockeye migration and spawning period. For the duration of the 2005 sockeye migration and spawning period, 85 hours had turbidity values greater than 100 NTU (Figure 5.44; Section 5.5.2). Elevated turbidity and SSC can have negative behavioral and physiological effects on adult sockeye, including negative effects on predator avoidance, territory selection, mate selection, homing and migration, gill function and integrity, respiration, and blood physiology. The high road densities in spawning tributaries (>4.0 mi/mi^2), extensive clear cutting (~98% of Umbrella Creek and Big River watershed clear-cut at least once), increased channel instability, mass wasting events, and other land use activities (e.g. agriculture) all contribute to elevated turbidity and SSC levels in tributaries. Dozens of observations of sediment inputs violating State water quality standards have been made during the last decade within the primary sockeye spawning tributaries, but no attempt to quantify the magnitude that turbidity and SSC have increased due to land use activities has been made (see Sections 4.4.1.5, 4.4.2.5, 4.4.3.5, 4.4.4.5.1, and 5.5.2). Note: the impact of SSC levels on other species may be significantly different than the impact on adult sockeye.

6.2.7.5 Research and Monitoring

Hypothesis 23: Weir trapping operations in Umbrella Creek increase susceptibility to predation and/or result in direct mortality during trapping.

LEVEL OF IMPACT: Negligible
CERTAINTY OF IMPACT: High

RATIONALE: Detailed records are kept regarding any direct mortality of sockeye during trapping in Umbrella Creek. Few instances have been recorded when sockeye have been directly impacted. Nonetheless, low numbers of sockeye salmon have been injured and in some cases killed by weir and trapping operations by becoming wedged between weir and trap pickets. Frequent monitoring of the weir and trap operation ensures that fish stress and mortality levels are adequately minimized. Predation at or near the Umbrella Creek weir has not been observed.

6.2.8 Adult Sockeye Spawning in Tributaries

The primary limiting factors affecting sockeye salmon spawning in tributaries include predation (Section 6.2.8.1), holding pool quantity and quality (Section 6.2.8.2), reduced quantity suitable spawning substrate (Section 6.2.8.3), streamflow (Section 6.2.8.4), kokanee-sockeye interactions (Section 6.2.8.5), water quality (Section 6.2.8.6), and research and monitoring (Section 6.2.8.7).

6.2.8.1 Predation

Hypothesis 24: Adult sockeye predation in tributaries occurs at low levels and is not likely a significant limiting factor.

LEVEL OF IMPACT: Low
CERTAINTY OF IMPACT: Moderate

RATIONALE: Hughes et al. (2002) concluded that there is very little evidence of predation mortality on spawning sockeye in Umbrella Creek based on tagging, tracking, genetic sampling, and spawning ground surveys. In 2000, seven adult sockeye tagged with CART tags were tracked in Umbrella Creek, and all were observed to have successfully spawned (see Sections 5.5.5, 5.5.5.1, 5.5.5.1.1, 5.5.5.1.2, and 5.5.5.2).

6.2.8.2 Holding Pool Quantity and Quality

Hypothesis 25: Current holding pool frequency and volume does not significantly affect adult sockeye salmon spawning.

LEVEL OF IMPACT: Negligible
CERTAINTY OF IMPACT: Moderate

RATIONALE: Holding pool frequency within the primary spawning areas in Umbrella Creek and Big River ranges from poor to good depending upon the channel habitat segment (Figure 4.49 and Figure 4.59). Pool habitat quality (frequency, complexity, depth, size) can be characterized as intermediate within the primary spawning areas of Umbrella Creek and Big River (Sections 4.4.1.3, 4.4.2.3, and 5.5.4.1). Once sockeye salmon begin the spawning process, they become territorially focused on protecting their respective redds, and utilization of pool habitat becomes much less important (than during the holding period - Section 6.2.7.2). Reduced pool quality within the primary tributary spawning grounds is therefore thought to have a negligible impact on sockeye salmon spawning success.

6.2.8.3 Quantity of Suitable Spawning Habitat

Hypothesis 26: Riparian forest removal, yarding and equipment operation in and across streams, stream cleaning and wood removal, as well as increased sediment production and delivery to streams has decreased the quantity of suitable spawning habitat (i.e., gravel) available to tributary spawning sockeye.

LEVEL OF IMPACT: Low
CERTAINTY OF IMPACT: High

RATIONALE: Gravel storage behind large woody debris has been systematically reduced throughout sockeye spawning tributaries (Section 5.5.4.2.2). This has been coupled with increased fine sediment delivery to mainstem spawning reaches, together altering the distribution and availability of suitable spawning gravel. Some mainstem sections (e.g., lower Big River) have been entirely transformed from gravel bed to sand bed (see Kramer's [1953] substrate description). However, at the watershed scale, gravel quantity is still high, but with reduced quality (Section 5.5.4.2) and stability (Section 5.5.4.3). Currently the effect of reduced gravel quantity on tributary spawning sockeye is low, but as the population increases, the effects of lost habitat will result in increased redd superimposition and reduced freshwater productivity.

6.2.8.4 Streamflow

Hypothesis 27: Streamflow variability can shift the distribution of spawning from "normal" positions in the channel, to the channel margins (e.g. during extended periods of high flow) or low in the thalweg (e.g. during periods of extended low flow) resulting in egg deposition in less optimal sites, where eggs are more susceptible to dewatering or scouring.

LEVEL OF IMPACT: Low
CERTAINTY OF IMPACT: Moderate

RATIONALE: Extended periods of high streamflow (caused by high storm frequency and intensity) can shift the distribution of spawning from "normal" positions in the channel to the margins, where velocity and depth more closely match the preferred conditions (e.g., Ames and Beecher 2001). When this occurs and is followed by normal or low flows, eggs in redds constructed along the channel margins or in less optimal positions in the channel may experience increased mortality during incubation due to redd dewatering or fine sediment intrusion. Extended dry periods yielding low flows following more or less "normal" flow conditions can produce the same effect with respect to redd dewatering. Conversely, below average flows during spawning that force fish to spawn low in the channel (thalweg), followed by large flood events, can increase susceptibility to redd scour (Ames and Beecher 2001; Lapointe et al. 2000; see Section 5.5.4.3). Thus, for sockeye spawning in compound channels under variable discharge regimes, there is a tradeoff between spawning low in the cross-section and risking scour mortality versus spawning high along channel margins and risking redd desiccation or sedimentation-related mortality (see Section 5.5.1.3)

6.2.8.5 Kokanee-Sockeye Interactions

Hypothesis 28: Kokanee spawning with sockeye salmon in tributaries occurs at extremely low levels and the genetic impacts on the sockeye population are minimal.

LEVEL OF IMPACT: Negligible to Low
CERTAINTY OF IMPACT: Moderate

RATIONALE: Kokanee-sockeye interactions are thought to be minimal in Umbrella Creek since few kokanee spawn in this stream system. However, sockeye spawning with kokanee-size *O. nerka* in Umbrella Creek has been observed and documented on several occasions. Kokanee spawning in the mainstem of Big River is very rare. A review of nearly 200 spawning ground surveys (1970-2005) conducted in the mainstem of Big River during the kokanee spawning season yielded only one observation of kokanee, and these fish were not observed spawning. The impact of kokanee-sockeye interactions in Umbrella Creek and Big River was rated as negligible. Within Crooked Creek, kokanee abundance is far greater than sockeye abundance and peak kokanee counts per mile averaged 100-500 during years with complete surveys. Competition and interaction between kokanee and any sockeye present in Crooked Creek is expected to be fairly common. Kokanee spawn timing is slightly earlier than observed sockeye spawn timing, which may act to minimize interaction and gene flow between these populations. Hatchery releases designed to introduce sockeye into Crooked Creek no longer occur due to concerns over sockeye-kokanee interactions and the fact that the two groups represent discrete populations of *O. nerka*.

6.2.8.6 Water Quality

Hypothesis 29: Elevated turbidity and SSC levels during adult tributary spawning reduces the spawning fitness of sockeye salmon, increases egg retention rates and pre-spawning mortality, and affects the behavioral process of mate selection.

LEVEL OF IMPACT: Low
CERTAINTY OF IMPACT: Moderate

RATIONALE: High turbidity levels, which are an indicator of SSC, have been recorded in Ozette spawning tributaries, especially Umbrella Creek and Big River (peak values >500 NTU). Peak streamflow and turbidity events are common during the sockeye migration and spawning period. For the 2005 sockeye migration and spawning period, 85 hours monitored had turbidity values greater than 100 NTU (Figure 5.44; Section 5.5.2). Elevated turbidity and SSC can have negative behavioral and physiological effects on adult sockeye, including negative effects on predator avoidance, territory selection, mate selection, homing and migration, gill function and integrity, respiration, and blood physiology. The high road densities in spawning tributaries (>4.0 mi/mi^2), extensive clear cutting (~98% of Umbrella Creek and Big River watershed clear-cut at least once), increased channel instability, mass wasting events, and other land use activities all contribute to elevated turbidity and SSC levels in tributaries. Dozens of observations of sediment inputs violating State water quality standards have been made during the last decade within the primary sockeye spawning tributaries, but no attempt to quantify the magnitude that turbidity and SSC have increased due to land use activities has been made (see Sections 4.4.1.5, 4.4.2.5, 4.4.3.5, 4.4.4.5.1, and 5.5.2). Note: the impact of SSC levels on others species may be significantly different than the impact on adult sockeye.

6.2.8.7 Research and Monitoring

Hypothesis 30: Spawning ground surveys result in the disturbance of spawning sockeye but do not result in direct adult sockeye mortality. Stress caused by human encounters on the spawning grounds results in negligible increases in egg retention and therefore does not affect overall egg-to-fry survival.

LEVEL OF IMPACT: Negligible
CERTAINTY OF IMPACT: Moderate

RATIONALE: Spawning ground surveys are conducted approximately every 7 to 10 days within the primary sockeye spawning reaches. Surveyors are trained to avoid or minimize the disturbance of spawning sockeye. Years of spawning ground surveys in Umbrella indicate that spawning sockeye salmon pay little attention to surveyors and therefore little if any impact occurs. For impacts on incubating eggs, see Section 6.2.9.7

6.2.9 Sockeye Egg Incubation in Tributaries

Identified limiting factors affecting sockeye salmon egg incubation in tributaries include high levels of fine sediment (Section 6.2.9.1); channel stability and floodplain alterations (Section 6.2.9.2); streamflow (Section 6.2.9.3); water quality (Section 6.2.9.4); competition (Section 6.2.9.5); predation (Section 6.2.9.6); and research and monitoring (Section 6.2.9.7).

6.2.9.1 Fine Sediment

Hypothesis 31: High levels of fine sediment (<0.85mm) in spawning gravels reduce intra-gravel flow, reduce oxygenation of redds, and increase fry entombment, resulting in decreased egg-to-fry survival.

LEVEL OF IMPACT: High
CERTAINTY OF IMPACT: Moderate

RATIONALE: High levels of fine sediment have been documented from core sample data from spawning gravels in Ozette tributaries (see Sections 4.4.1.4, 4.4.2.4, and 4.4.3.4). During incubation, salmonid eggs require sufficient water flow to supply egg pockets with oxygen and carry away waste products (Bjornn and Reiser 1991). Water circulation through salmon redds is a function of redd porosity, permeability, and hydraulic gradient (Bjornn and Reiser 1991). Fine sediment that settles into redds during the egg incubation period can impede water circulation and fry movement, which can result in decreased egg-to-emergence survival (Bjornn and Reiser1991). Studies throughout the Pacific Northwest have found that increased levels of fine sediment (<0.85mm) in spawning gravels decreases egg to emergence survival (Cederholm et al. 1981; Bjornn and Reiser 1991; McHenry et al. 1994). McHenry et al. (1994) found that coho and steelhead egg to alevin survival decreased drastically when fine sediment (<0.85mm) exceeded 13% (volumetric method) in Olympic Peninsula streams. Numerous other researchers have also found that survival to emergence relates negatively to the percentage of fines in gravel (McNeil and Ahnell 1964; Koski 1966; Cederholm et al. 1981; Cederholm et al. 1982; Tappel and Bjornn 1983; Tagert 1984; Chapman 1988).

The high density of poorly constructed, surfaced, and maintained roads along with extensive, frequent timber clear-cutting in most sub-basins from the 1950s to present have resulted in increased sediment production and delivery to tributaries. Additionally, mass wasting, channel and bed destabilization, wood removal, decreased bank stability, and channel incision have increased sediment production and delivery to the stream network within the primary sockeye spawning tributaries. The exact degree that each input specifically increases or alters fined sediment levels in spawning gravel remains unknown (Section 5.5.4.2.1). Duplicating sediment sampling conducted by McHenry et al. 1994 could help answer important questions regarding current and past fine sediment levels, as well as aid in predicting actions and timeframes required for gravel quality to reach desired conditions for adequate fry production.

Hypothesis 31A: Increased sediment production and delivery to sockeye tributaries from land use activities (e.g. road building and clearcut logging) has increased the quantity of fine sediment in spawning gravels (Section 5.5.4.2.1).

6.2.9.2 Channel Stability and Floodplain Alterations

Hypothesis 32: Decreased channel stability and floodplain alterations have reduced egg-to-fry emergence survival in sockeye tributaries.

LEVEL OF IMPACT: Moderate
CERTAINTY OF IMPACT: Low

RATIONALE: There is no uncertainty that the bed and banks of sockeye spawning tributaries have been destabilized by land use and management practices over the last 100 years. What remains uncertain is the degree to which instability has lowered egg-to-fry survival during gravel bed incubation. Sediment transport and scour depth data have not been systematically collected along with fine sediment data at representative sockeye spawning locations. These data gaps need to be filled to assess the impact of wood removal, base level changes, incision, channelization, watershed sediment delivery, movement of sediment pulses, and streamflow magnitude on egg-to-fry survival. For a complete discussion on channel stability see Section 5.5.4.3.

Hypothesis 32A: Reduced large wood debris delivery from riparian logging and direct large woody debris removal has decreased the stability of the tributary channel beds and banks, increased coarse sediment transport and scour, and increased fine sediment delivery from eroding banks (Section 5.5.4.3).

Hypothesis 32B: Large woody debris removal from Ozette River has reduced the average lake levels resulting in channel incision in tributaries, and thus decreased channel stability.

Hypothesis 32C: Channelization of floodplain tributaries (i.e., Big River) from paved roads, unpaved roads and railroad grades, bank armoring (e.g., rip-rap and cars), channel relocation, and bridge crossings has decreased channel complexity, reduced large wood delivery, reduced floodplain connectivity, concentrated flood energy in the channel, and thus decreased channel stability (Sections 5.5.4.3 and 5.5.3).

Hypothesis 32D: Increased water runoff from road networks and vegetation clearing has increased the magnitude of common peak flood events, increased the frequency and magnitude of sediment transport events, and thus decreased channel stability (see Section 5.5.1.2.2).

Hypothesis 32E: Increased production of coarse and fine sediment from upland sources such as landslides and roads, and in channel sources such as eroding banks, has delivered large volumes of sediment to the mainstem channel networks, which has promoted stream bed instability as this material migrates downstream (5.5.4.2.1).

6.2.9.3 Streamflow

Hypothesis 33: Streamflow variability and human-caused hydrologic changes have decreased egg-to-fry survival.

LEVEL OF IMPACT: Unknown
CERTAINTY OF IMPACT: NA

RATIONALE: Lack of long-term hydrologic data sets in the Ozette Watershed preclude precise quantification of any potential changes to hydrology and flow regimes from land use and channel modifications. The high road densities in sockeye tributaries (>4.0 mi/mi^2), extensive clear cutting (>95% of sockeye watersheds clear-cut at least once), and lack of floodplain connectivity (e.g., channelization and wood removal) cumulatively lead to the hypothesis that hydrologic change has occurred in Ozette tributaries, but with an unknown magnitude (Section 5.5.1.2.2). This is consistent with the voluminous literature that water yield changes begin following a significant (10 to 25%) reduction of forest vegetation cover, with the highest impacts in conifer forests in high precipitation zones. The quantification of this potential limiting factor remains a data gap.

Hypothesis 33A: Increased water runoff from road networks and vegetation clearing has increased the magnitude of common peak flood events, increased the frequency and magnitude of sediment transport events, and thus decreased channel stability (Section 5.5.1.2.2).

Hypothesis 33B: Reduced watershed storage of water due to hydrologically connected road networks, reduced vegetation interception, and lack of floodplain connectivity (e.g., channelization and wood removal) has decreased base flow levels and increased the susceptibility of redds to becoming dewatered during incubation (Section 5.5.1.2.2).

6.2.9.4 Water Quality

Hypothesis 34: High levels of turbidity and SSC result in fine sediment deposition in sockeye redds, decreasing egg survival.

LEVEL OF IMPACT: High
CERTAINTY OF IMPACT: Moderate

RATIONALE: High turbidity and SSC have been recorded in Ozette spawning tributaries, especially Umbrella Creek and Big River (peak values >500 NTU). Peak streamflow and turbidity events are common during the sockeye incubation period. The high road densities in spawning tributaries (>4.0 mi/mi^2), extensive clear cutting (~98% of Umbrella Creek and Big River watershed clear-cut at least once), increased channel instability, mass wasting events, and other land use activities such as agriculture all contribute to elevated turbidity and SSC levels in tributaries. Dozens of observations of sediment inputs violating State water quality standards have been made during the last decade within the primary sockeye spawning tributaries, but no attempt to quantify the magnitude that turbidity and SSC have increased due to land use activities has been made (see Sections 4.4.1.5, 4.4.2.5, 4.4.3.5, 4.4.4.5.1, and 5.5.2). Degraded water quality conditions contribute to fine sediment levels in spawning gravels (Section 6.2.9.1), which reduces intra-gravel flow, reduces oxygenation of redds and eggs, and increases fry entombment.

6.2.9.5 Competition (Redd superimposition)

Hypothesis 35: Sockeye salmon spawn in high densities and competition for optimal spawning sites is intense, resulting in redd superimposition and reduced egg-to-fry survival.

LEVEL OF IMPACT: Negligible to Moderate
CERTAINTY OF IMPACT: High

RATIONALE: Within Umbrella Creek, spawning competition for suitable spawning sites and mates is more intense than in Big River and Crooked Creek (see Section 5.5.6). In recent years, large numbers (1,000 to 4,000) of spawning sockeye have utilized habitat in a fairly discrete section of Umbrella Creek (most spawning has been observed in a 2.2-mile-long stream reach). Competition for spawning habitat within this reach can be intense, and redd superimposition plays a significant role in determining the number of fertilized eggs that ultimately make it into the spawning gravels to incubate. During the peak spawning period, downstream of mass-spawning areas in Umbrella Creek, hundreds of sockeye eggs can be seen along the bottom of the stream or being transported downstream. The degree of redd superimposition likely varies depending upon the number of spawners returning to Umbrella Creek, as well as how they distribute themselves during the spawning period. Redd superimposition at levels occurring in Umbrella Creek likely reduces the overall egg-to-fry survival rate, but net production is not thought to be reduced. That is to say, if fewer sockeye spawned in Umbrella Creek, the net fry production would be reduced, not increased. However, if sockeye were distributed evenly throughout all suitable habitats, egg-to-fry survival would increase, as would net fry production. Redd superimposition has a negligible impact in overall egg-to-fry survival in Big River and Crooked Creek.

6.2.9.6 Predation

Hypothesis 36: Predation on sockeye eggs in tributaries occurs at low levels and is not likely a significant limiting factor.

LEVEL OF IMPACT: Low
CERTAINTY OF IMPACT: Low

RATIONALE: Egg predation in tributaries has not been thoroughly investigated, but potential impacts are thought to be low (see Section 5.5.5). Egg pumping tests conducted in 1998 and 1999 did not indicate that significant egg predation was occurring in Umbrella Creek. Tributary egg predation largely remains a data gap.

6.2.9.7 Research and Monitoring

Hypothesis 37: Spawning ground surveys result in low levels of direct sockeye mortality caused by sockeye redd disturbance.

LEVEL OF IMPACT: Low
CERTAINTY OF IMPACT: High

RATIONALE: Spawning ground surveys are conducted approximately every 7 to 10 days within the primary sockeye spawning reaches. Surveyors are trained to identify and record all types of spawning activity, even under difficult or cryptic situations. Surveyors are also trained to avoid walking in areas suitable for spawning and to walk along channel margins and dry bars. Observed redds are flagged on the nearest branch or tree for future reference. Over time, redds can become masked in appearance because of algae growth, water depth, or bedload transport. It remains possible that surveyors could still walk or step on redds and crush eggs. However, years of experience and the precautions mentioned above keep impacts low.

6.2.10 Tributary Fry Emergence and Dispersal

Identified limiting factors affecting sockeye salmon during the fry emergence and dispersal phase in Lake Ozette tributaries include predation (Section 6.2.10.1), streamflow (Section 6.2.10.2), and water quality (Section 6.2.10.3).

6.2.10.1 Predation

Hypothesis 38: Predation of sockeye fry during emergence, emigration, and dispersal reduces the number of fry rearing in the pelagic zone of the lake.

LEVEL OF IMPACT: Moderate
CERTAINTY OF IMPACT: Low

RATIONALE: Estimates of post-release survival for 1998 brood year Umbrella Creek Hatchery released fingerlings moving downstream from RM 4.8 to RM 0.8 ranged from 74% to 40% (see Section 5.5.5). Burgner (1991) reviewed several studies conducted to determine fry predation rates for riverine spawned sockeye fry emigrating to nursery lakes and found widely ranging values: 63%-84% (Scully Creek, Lake Lakelse, 4 yrs), 66% (Six Mile Creek, Babine Lake, 1 yr), 13%-91% (Karymaiskiy Spring, Kamchatka Peninsula, 8 yrs), and 25%-69% (Cedar River, Lake Washington). Large numbers of predators (cottids, cutthroat, coho yearlings) were captured incidentally in fyke net trapping of natural-origin fry in Umbrella Creek during spring 1999. Predators consumed sockeye fry relative to coho fry at a ratio of 8.3 to 1, based on the relative abundance of each species, suggesting that sockeye fry were the preferred prey species during the months of April and May even though coho fry abundance was much greater (see also Section 3.1.7).

Hypothesis 38A: Small population size and reduced egg-to-fry survival reduce the overall number of fry and increase the relative impact of predators on the prey population.

6.2.10.2 Streamflow

Hypothesis 39: Low streamflows at emergence and emigration hinders migration to the lake, increasing transit time, exposure time in the fluvial environment, and susceptibility to predation. Streamflows can be further reduced by land use activities and changes in water retention capability.

LEVEL OF IMPACT: Low
CERTAINTY OF IMPACT: Low

RATIONALE: Sockeye salmon emerge from the spawning gravel in Ozette tributaries from March to May (see Section 3.1.7). This is generally a period of decreasing discharge because of reduced precipitation inputs following the mid-winter maximum monthly precipitation (see Section 5.5.1.1). Climatic variability in precipitation timing and the stochastic nature of weather events are phenomena that sockeye salmon have generally adjusted to under natural conditions and population levels. However, unusually low streamflow and precipitation during tributary emigration can affect the rate of sockeye emigration (e.g., spring 2004) and likely their mortality (Section 5.5.1.3).). Tabor et al. (1998) suggested that predation rates were low in most sites studied in the Cedar River during the 1997 fry emigration to Lake Washington because of high streamflow. They found that at mid-channel sites, where velocities were moderate or high, little predation of sockeye salmon was observed. Seasonal droughts and reduced streamflow could be exacerbated by land use changes. These changes may affect the magnitude, but not timing, of base flows. Land use (including channel modifications) could affect low base flow magnitudes to an unknown degree, which under natural conditions with higher sustained base flows, may have allowed sockeye to emigrate into Lake Ozette during a shorter time period. Climate change into the future could alter the timing and magnitude of flows needed to transport sockeye fry down into Lake Ozette.

6.2.10.3 Water Quality

Hypothesis 40: Increased sediment production and delivery from tributary watersheds has increased turbidity and SSC levels during sockeye fry emigration, which has reduced sockeye fry fitness, increased gill abrasion, and altered oxygen uptake.

LEVEL OF IMPACT: Low
CERTAINTY OF IMPACT: Moderate

RATIONALE: High turbidity levels, which are an indicator of SSC, have been recorded in Ozette tributaries, especially Umbrella Creek and Big River (peak values >500 NTU). Peak streamflow and turbidity events are common during the sockeye fry emigration period. For the 2005 sockeye emigration period, 15 hours monitored for water quality had turbidity values greater than 100 NTU (Figure 5.44; Section 5.5.2). However, at least for 2005, the spawning period was shown to have greater turbidity levels than the fry emigration period. Generally, there is less average monthly precipitation during emigration, and thus flood events carrying high sediment loads are less frequent than during adult spawning. However, high turbidity and sediment levels still occur during emigration. Elevated turbidity and SSC can have negative behavioral and physiological effects on juvenile sockeye, including negative effects on predator avoidance, swimming and emigration efficiency, gill function and integrity, respiration, and blood physiology. The high road densities in spawning tributaries (>4.0 mi/mi^2), extensive clear cutting (~98% of Umbrella Creek and Big River watershed clear-cut at least once), increased channel instability, mass wasting events, and other land use activities all contribute to elevated turbidity and SSC levels in tributaries. Dozens of observations of sediment inputs violating State water quality standards have been made during the last decade within the primary sockeye spawning tributaries, but no attempt to quantify the magnitude to which turbidity and SSC have increased due to land use activities has been made (see Sections 4.4.1.5, 4.4.2.5, 4.4.3.5, 4.4.4.5.1, and 5.5.2).

6.2.11 Juvenile Freshwater Rearing

Identified limiting factors affecting sockeye salmon during the juvenile freshwater rearing phase in Lake Ozette are predation (Section 6.2.10.1), fisheries impacts (Section 6.2.11.2), disease (Section 6.2.11.3), and food availability/competition (Section 6.2.11.4).

6.2.11.1 Predation

Hypothesis 41: Changes in predator-prey abundances in the lake environment have increased the rate at which juvenile sockeye are consumed by predators (e.g. cutthroat trout, northern pikeminnows) and resulted in decreased fresh water survival, as well as an overall decrease in the number of sockeye returning to spawn.

LEVEL OF IMPACT: High
CERTAINTY OF IMPACT: Moderate

RATIONALE: A predation study conducted by Beauchamp et al. (1995) suggests that cutthroat trout consume most of the fry produced within the watershed (see Section 5.4.5). Other factors such as harvest and habitat degradation may have reduced the sockeye population to levels where predators consumed the majority of juveniles. However, it is thought that increased sockeye fry recruitment to the lake from tributary production has decreased the rate of predation since Beauchamp conducted studies of Ozette *O. nerka* predation. Age-0 *O. nerka* population dynamics have likely changed dramatically since the early 1990s, commensurate with the advent of substantial fry production by the tributary hatchery program. Future studies should specifically monitor piscivorous fish predation of juvenile sockeye in the lake. Quinn (2005) found that average survival from fry-to-smolt for sockeye in other lake systems averages roughly 25% and that predation is presumably responsible for most of the mortality in the sockeye lakes studied.

Hypothesis 41A: Changes in fisheries management requiring the release of cutthroat trout (effective in 2002) in Lake Ozette will increase the abundance of large cutthroat trout, resulting in increased sockeye predation and a net reduction in freshwater survival and subsequent recruitment to the lake unless the age-0 *O. nerka* population size increases (Section 5.3.4.2.6).

Hypothesis 41B: Introduction of non-native species (e.g. yellow perch, bass) has increased predation rates on sockeye salmon, but because there is little spatial/temporal overlap between non-native species and sockeye salmon the overall impact is low (Section 5.3.4.1.5).

Hypothesis 41C: Increased sockeye abundance in Lake Ozette, mainly from increased production in tributaries acts as a buffer for beach spawned juveniles, decreasing the impact of predation on the sub-population.

6.2.11.2 Fisheries Impacts

Hypothesis 42: There are no directed sockeye/kokanee fisheries in Lake Ozette and therefore there are no direct sockeye harvest impacts occurring within the lake.

LEVEL OF IMPACT: None
CERTAINTY OF IMPACT: High

RATIONALE: The lake is closed to salmon fishing and therefore there are no impacts on sockeye attributable to directed sockeye fisheries occurring in the lake. Incidental hooking and non-directed impacts are discussed in Hypothesis 43 below.

Hypothesis 43: Incidental hooking and catching of juvenile sockeye salmon occurs in low numbers within the lake during sport fisheries targeting trout, bass, or other non-salmon species. Incidental hooking or catching of juvenile sockeye salmon has a negligible effect on the sockeye population.

LEVEL OF IMPACT: Negligible
CERTAINTY OF IMPACT: Moderate

RATIONALE: The smolt emigration period begins before the sport fishery opening on the lake. The majority of the sockeye smolts are in the lake during the first few weeks when the lake is open to fishing. Lake Ozette has low fishing pressure, which reduces the potential impact of incidental sockeye encounters. ONP fishing regulations require the immediate release of all salmonids. Age 0 sockeye are unlikely to be susceptible to fishing due to their small size during the period when the lake is open to sport fishing. There are no data regarding fishing pressure (e.g. angler days) or non-targeted sockeye encounters within the lake; these conclusions are based on the experience and knowledge of members of the limiting factors rating workgroup about the Lake Ozette sport fisheries.

6.2.11.3 Disease

No systematic monitoring of juvenile sockeye health in the lake occurs. The degree to which disease may affect the population is unknown (see Section 5.4.6).

6.2.11.4 Food Availability/Competition

Hypothesis 44: Food availability and competition for food resources has a negligible effect on juvenile sockeye productivity in Lake Ozette.

LEVEL OF IMPACT: Negligible
CERTAINTY OF IMPACT: Moderate

RATIONALE: Beauchamp et al (1995) estimated that juvenile sockeye and all year classes of kokanee consumed less than 1% of the monthly standing stock of *Daphnia pulicaria* > 1.0 mm in size, suggesting that food availability for rearing fish was not limiting *O. nerka* productivity. All researchers (Bortleson and Dion 1979; Dlugokenski et al. 1981; Blum 1988; Beauchamp and LaRiviere 1993), independent of methodologies, have concluded that Lake Ozette sockeye productivity and survival are not limited by food availability or competition for food resources (see Section 5.4.4).

6.2.12 Seaward Migration

Identified limiting factors affecting sockeye salmon during the juvenile freshwater rearing phase in Lake Ozette include predation (Section 6.2.12.1), Ozette River habitat conditions (Section 6.2.12.2), water quality (Section 6.2.12.3), streamflow (Section 6.2.12.4), estuarine habitat conditions(Section 6.2.12.5), fisheries impacts (Section 6.2.12.6), disease (Section 6.2.12.7), and research and monitoring (Section 6.2.12.8).

6.2.12.1 Predation

Hypothesis 45: Predation in the Ozette River during smolt emigration reduces the number of juvenile sockeye entering the ocean, therefore reducing freshwater survival.

LEVEL OF IMPACT: Moderate
CERTAINTY OF IMPACT: Moderate

RATIONALE: Smolt trapping and adult sockeye weir enumeration data indicate that large numbers of predators congregate in the Ozette River during the smolt emigration period. Stomach analysis of northern pikeminnow indicates that they actively feed on sockeye and coho smolts (see Section 5.3.4.1.3). The impact on the population was rated as moderate at low sockeye abundance and low at moderate and high smolt abundances.

Hypothesis 45A: Weir and trapping structures used for research and monitoring in the Ozette River delay and spatially confine seaward migrating smolts, providing increased predator opportunity and efficiency (see Section 6.2.12.8).

Hypothesis 45B: Low streamflows in the Ozette River lengthen migratory time, increasing the duration of sockeye smolt exposure to aquatic predators (Section 6.2.12.4).

Hypothesis 45C: Low levels of LWD and reduced pool complexity increases vulnerability to predation and reduces the abundance and quality of refuge areas (Section 6.2.12.2).

6.2.12.2 Ozette River Habitat Conditions

Hypothesis 46: Low levels of LWD and reduced pool complexity increase the vulnerability of sockeye smolts to predation and reduces the quantity and quality of refuge habitats.

LEVEL OF IMPACT: Low
CERTAINTY OF IMPACT: Moderate

RATIONALE: The loss of large (>50 cm diameter) LWD in the Ozette River through removal operations has undoubtedly resulted in reduced habitat complexity throughout much if not all of the Ozette River. Riparian forest removal adjacent to the upper 0.4 miles of the Ozette River has reduced LWD inputs, delaying the recovery and habitat potential of the upper river. Lake Ozette sockeye have not been observed spawning or rearing in the Ozette River and therefore the direct effect on sockeye in the Ozette River are likely limited (Section 5.3.1.1). Habitat simplification mainly affects sockeye smolts by reducing refuge habitat, making sockeye more susceptible to predation.

6.2.12.3 Water Quality

Hypothesis 47: High stream temperatures and low frequency, high intensity turbidity events reduce the fitness of juvenile sockeye salmon emigrating to the Pacific Ocean, and results in decreased survival in the river and during the early marine life history phase.

LEVEL OF IMPACT: Low
CERTAINTY OF IMPACT: Moderate

RATIONALE: High stream temperatures and low frequency, high intensity turbidity events occur during the sockeye smolt emigration period. However, the majority of the sockeye smolt population emigrates before stream temperatures reach >16°C. Only a small fraction of sockeye smolts encounter temperatures exceeding 18°C. Low frequency, high intensity turbidity events resulting in moderate physiological stress occur during the smolt emigration period. During the month of April, when average Ozette River streamflow is still around 400 cfs, SS inputs from Coal Creek would normally be diluted by flow contributions from the Ozette River. However, dilution of 50% of the SSC would have a negligible effect on the predicted effects on sockeye salmon at the concentration levels estimated to occur following a 2-inch precipitation event (Section

5.3.3.2). Predicted higher suspended sediment concentrations in Coal Creek during the month of April would likely have a lower severity index (in the Ozette River) due to the effect of dilution caused by higher streamflows in the Ozette River.

From May to August when lake level is typically low, no or very limited dilution from the Ozette River would be expected, because high intensity rainfall events usually reverse the flow of the Ozette River (during low lake level periods) and Ozette River flow is made up almost entirely of Coal Creek discharge. Severity indexes estimated from data tables in Newcombe and Jensen (1996) indicate that for moderately common storm events (10% to 3% probability of occurrence on any given day from May-August) in Coal Creek, moderate behavioral and physiological stress could occur for juvenile sockeye (see Section 5.3.3.2 and Table 5.2). Effects could include moderate physiological stress (6); moderate habitat degradation and impaired homing (7); and major indications of physiological stress and poor condition (8). During the month of May, no more than 7.5% of the smolt populations are expected to encounter SSC predicted to result in moderate physiological stress.

6.2.12.4 Streamflow

Hypothesis 48: Sedimentation in the Ozette River from Coal Creek has reduced the quantity of water available as streamflow from the lake at a given stage. Changes in this stage discharge relationship, changes in hyporheic and surface flow conditions, increased lake evapotranspiration, and reductions in tributary baseflow inputs have reduced summer low flows. Reduced streamflows affect water quality, predation rates and efficiency, and migration, reducing the fitness of emigrating sockeye smolts.

LEVEL OF IMPACT: Unknown
CERTAINTY OF IMPACT: NA

RATIONALE: The overall degree to which flow has been reduced during the sockeye smolt emigration period remains unquantified. Details on Ozette River hydrology can be found in Sections 4.3.6, and 5.3.2. The most substantial reductions in streamflow occur from mid- to late-summer (when streamflows are naturally lower) and when sockeye smolts are not present. Quantification of streamflow reduction during smolt emigration, and potential impacts remain a data gap.

6.2.12.5 Tidal Prism and Physical Estuarine Habitat Conditions

Changes in the tidal prism and estuarine habitat conditions appear to have occurred during the last 50 years (see Section 4.1). The cause of these apparent changes is poorly understood, as are the potential effects on Lake Ozette sockeye. Changes in the estuarine habitat conditions have an unknown impact on sockeye smolt survival. This potential limiting factor remains a data gap.

6.2.12.6 Fisheries Impacts

Hypothesis 49: There are no open fisheries within the Ozette River during the juvenile sockeye emigration period and therefore there are no impacts on sockeye salmon from permitted in-river fisheries.

LEVEL OF IMPACT: None
CERTAINTY OF IMPACT: High

RATIONALE: The river is closed to all sport fishing until August 1. When the river is open, selective fishery rules apply and all sockeye must be released immediately. Sockeye smolt emigration is complete by mid-June and therefore there are no impacts from fisheries.

6.2.12.7 Disease

No systematic monitoring of juvenile sockeye health occurs in the Ozette River. The degree which disease may affect the population is unknown (see Section 5.3.6).

6.2.12.8 Research and Monitoring

Hypothesis 50: Research and monitoring activities directed at migrating sockeye smolt (traps, weirs) result in almost no direct mortality. Low levels of indirect mortality associated with predation at the trapping site occur.

LEVEL OF IMPACT: Low
CERTAINTY OF IMPACT: High

RATIONALE: Smolt trapping data indicates that very few direct mortalities result from smolt trapping (<1% of all smolts encountered). The indirect effects of smolt trapping are discussed in the predation hypothesis above (see Section 6.2.12.1).

6.2.13 Marine Ocean Phase

6.2.13.1 Fishery Interception

Hypothesis 51: No directed Lake Ozette sockeye fisheries occur in the marine environment and therefore there are no impacts.

LEVEL OF IMPACT: None
CERTAINTY OF IMPACT: High

RATIONALE: No directed Lake Ozette sockeye fisheries occur in the marine environment and therefore there are no impacts.

Hypothesis 52: Non-directed fishery interceptions (from sport, commercial, and tribal salmon and ground fish fisheries) of Ozette sockeye occur at extremely low levels and the impact of past and current west coast fisheries is negligible.

LEVEL OF IMPACT: Negligible
CERTAINTY OF IMPACT: High

RATIONALE: PFMC (2004) states that Council Area (southern U.S. coastal sport, commercial, and tribal) fisheries have no measurable impact on sockeye salmon. An additional review of recent (1995-2004) sport catch in coastal Washington fishing areas and Washington Marine Areas 5 and 6 indicate that average sockeye catch is insignificant relative to the number of sockeye present. Partial time series sport catch data for these same areas from 1979 to 1994 further indicate that sport catch of sockeye salmon are negligible. Bycatch of sockeye in coastal whiting and bottom trawl fisheries also appears to be negligible, as few if any sockeye have been observed as bycatch. The early-return timing of Ozette sockeye substantially limits their occurrence in marine migratory areas when and where commercial and sport fisheries directed at other sockeye populations (e.g., Southeast Alaska, Northern British Columbia, and Fraser River stocks) occur (see Section 5.6.1.1).

6.2.13.2 General Marine Survival

Hypothesis 53: Survival in the marine environment is driven by large-scale climatic processes and variability in marine survival rates for sockeye salmon is significant. Ultimately, the number of adult sockeye returning to the Ozette River is largely defined by marine survival, which is driven by processes that are not controllable.

LEVEL OF IMPACT: High
CERTAINTY OF IMPACT: High

RATIONALE: Average mortality of large southern (< 55°N longitude) sockeye smolts in the marine environment averages 83% (Koenings et al. 1993). Mortality in the marine environment is likely the largest single mortality factor affecting Ozette sockeye. However, it is important to recognize that: 1) very high mortality rates in the marine environment are natural, and 2) there are no known direct actions that can be taken in the marine environment to improve survival for Ozette sockeye (see Section 5.6.1).

Hypothesis 53A: While marine survival is a critical component in determining the ultimate abundance of Lake Ozette sockeye, broad-scale, regional studies of decadal-scale productivity indicate that changes in marine survival played a limited role in the decline of Ozette sockeye.